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Structural Colours Based on Basic Structuration Theory of Photonic Crystals

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Abstract

With the rapid development of photonic crystals (PCs), PC structural colouration has gained great attention from many more researchers. Dyeing methods can benefit a lot from PC structural colours and become more environmentally friendly. This modified colouration is superior to the traditional ordinary and chemical dyes and pigments, because of the special characteristics of PC structural colours, such as high brightness, high saturation, never fading, iridescent effect, polarization phenomenon, and so on. In this work, the concept and clarification of PCs, the PC structural colour, the mechanism of structural colouration and various methods of preparing artificial PC are reviewed. Generally, PC can be divided into different types because of diverse spatial distribution characteristics of the photonic band gap. The basic principle of the structural colouration is explained in detail. In the process of producing structural colour, it is of great importance to synthesize silica nanoparticles by solvent change technique (SVT) and self-assembly gravity sedimentation method is described minutely in this paper. Meanwhile, the strengths and weakness of these methods are compared to select the best method for manufacturing structural colours. The applications of PC structural colour are summarized, and some problems are proposed which need to be solved in PC development in the future.

Keywords: Photonic Crystals; Structural Colour; Nano-particles; Structuration Theory; Solvent Varying Technique; Self-assembly; Gravity Sedimentation

1 Introduction

Colour is a visual effect on light produced by our eyes and brain combined with our life experience [1, 2]. Colours are visible to human eyes by three elements, including the light source, the object, and the observer. The ability of the human eye to discern colour is dependent on the performance of the eye cells located on the retina of the human eye. Different types of eye cells are sensitive to different wavelengths. When the human eye is stimulated by light, the photoreceptor cells on the retina of the human eye will change accordingly, forming a specific signal, which is then

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transmitted to the brain through the nervous system, and the brain translates the corresponding result [3, 4]. Light is a part of the electromagnetic spectrum, which is visible by the human eye. Therefore, colours are closely related to light. Visible light generally refers to electromagnetic waves with wavelengths between 380 nm and 780 nm. As can be seen in Fig. 1, the light of a specific wavelength produces a specific colour and the colours change from blue to red as the wavelength increases. The electromagnetic spectrum distribution is shown in Fig. 1, waves not within the visible spectrum range cannot be seen by human.

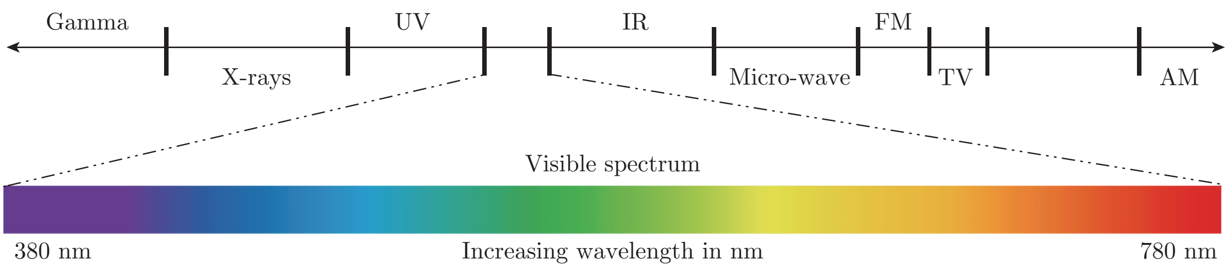

Fig. 1: Electromagnetic spectrum distribution

In general, there are two main sources of colours that people can perceive. One is pigmentary colours and the other is structural colours. Pigmentary colours, also known as chemical colours, exhibit diverse colours through selectively absorbing, reflecting, and transmitting light of a specific wavelength. As shown in Fig. 2, some examples of pigmentary colours can be seen, such as the colours of plants and food. The theory of molecular orbitals and electronic transitions can account for this colouration mechanism. Since the absorption and reflection of light by the pigment is isotropic, the colours observed from all angles and directions are consistent [5]. Structural colour is also called physical colour, and its colour generation mechanism is completely different from the chemical colour. It does not contain any pigmentation factors, but mainly forms the colour due to the interference, diffraction, and scattering happening between the special structure of the object itself and natural light [6, 7]. Many ordinary structural colours exist in our natural

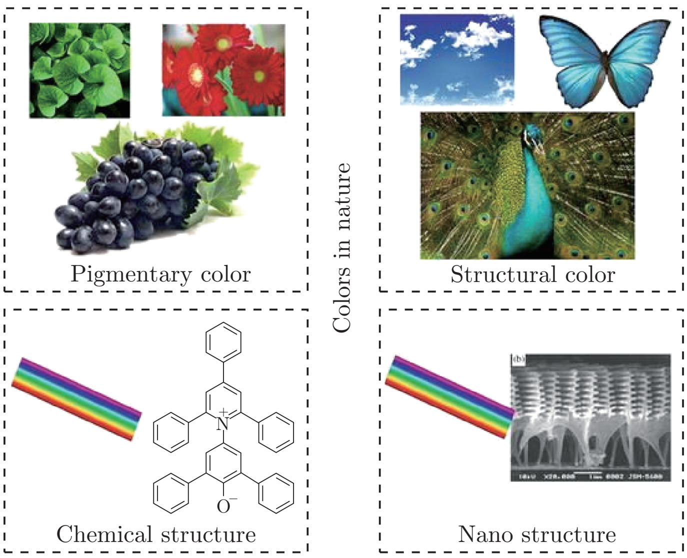

Fig. 2: Examples and mechanism of colour generation: (a) pigmentary colours, (b) structural colours. Copyright 2015, Springer [10]